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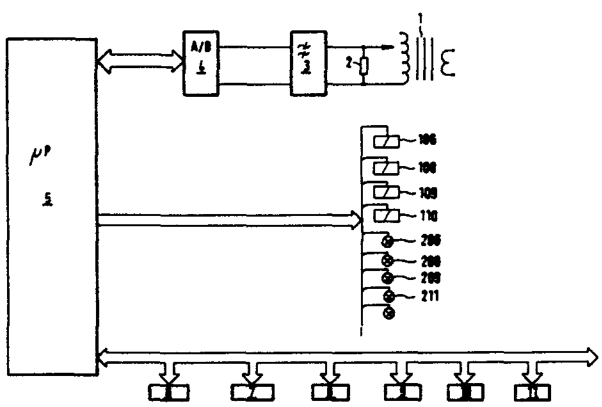
(54) **A new delayed action electrical protection device, depending on an adjusted magnitude.**

(57) This invention provides a delayed action electrical protection device which may be used for example to protect electrical lines and equipment against disturbances such as overload conditions and minimum voltage conditions. An analogue signal denoting the particular condition for which protection is to be provided is converted into a digital signal which is applied to a micro-processor. In the micro-processor this digital is compared with a prescribed value or values fed into the processor. The processor contains information relating to characteristic curves which define the time delay between the detection of a particular condition and the production of a tripping signal which may, for example, be used to interrupt the electrical circuit and/or provide an alarm. The time delay varies inversely with the magnitude of any disturbance and may, for example, be defined by the expression:–

$$\frac{K}{i^2-1}$$

where K is a constant; i equals $\frac{I}{I_n}$; where I is the measured current and $I_n$ is the prescribed value.



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" A NEW DELAYED ACTION ELECTRICAL PROTECTION DEVICE, DEPENDING ON AN ADJUSTED MAGNITUDE".

This invention enables a new electrical protection device to be obtained, which is controlled by a magnitude that is adjusted by a time relay depending upon it, and, as will be seen from the ensuing specification of the invention, it takes over the functions that are at present performed by different kinds of protection devices, and it can perform same with an increased degree of accuracy, while it furthermore combines them all, and obviates certain errors which up to now had been impossible to overcome.

Figure 1 is a diagram of the new protection device covered by this invention.

Figure 2 depicts a family of three characteristic curves as obtained by plotting the change over delay time, shown on the vertical axis, against a dependent magnitude which, in this case, is comprised by the ratio between the real current (I) flowing in the circuit to be protected, and the nominal current ($I_n$) thereof.

Notations as follows are used in these figures:

1. Transformer.
2. Resistance.
3. Band pass filter.
4. Analogue-to-Digital converter.
5. Microprocessor.
6. Desired nominal current value selector.
7. Desired additional constant time value selector.
8. Desired instantaneous trip value selector.
9. Desired watch time value selector.
10. Desired reset time value selector.
11. Desired locking time value selector.

106. Dependent time trip output relay.
108. Instantaneous trip output relay.
109. Second order alarm output relay.

110. Reset output relay.
206. Preset value (6) trip signal.
208. Preset value (8) trip signal.
209. Preset value (9) trip signal.
211. Preset value (11) trip signal.

For the sake of simplicity in the explanation, the invention is first described with reference to one of the functions it can perform (which is that concerned when it behaves in the same way as an overload relay), and thereafter reference will be made to the other functions it embodies.

Up to now, electro-mechanical relays of an induction disc design have been used as overload relays for generating time characteristic curves. Here the inertia of the disc caused errors to arise when obtaining such curves, and moreover it made the disc travel excessively in its angular motion when the current transformer secondary current descended, so that upon thus continuing to revolve, the disc would cause the trip circuit to close (this phenomenum being called over-reach), while furthermore the inertia thus produced would cause a considerable consumption in the current transformers, which made them increasingly expensive.

Subsequently, electronic circuits appeared, which generated inverted time functions. The relays provided in electronic circuits of this type have been shown to have superior features to those possessed by electro-mechanical relays, and thus improve upon the consumption and over-reach aspects, while furthermore they provided an improvement as regards repeatibility errors with respect to time measurement. However, the manufacture of these pieces of equipment is relatively complex, because of the selection that has to be made of the components which comply with the time characteristic curve requirements. These difficulties were partially overcome by incorporating circuits that were based on the use of analogue operational amplifiers, whose supply network possessed non-linear feedback components, which produced a non-linear transfer characteristic in the circuit. Nonetheless, such circuits involve complexities as regards obtaining a certain time characteristic curve, on the basis of a given transfer characteristic for such circuits. Moreover, since these circuits are analogue ones, they involve manufacturing difficulties, drifts, and the need to preset the input signal in order for the output signal to be directly proportional to the operational amplifier input signal (that is to say, the so called "offset" phenomenum, etc).

The present invention enables all the aforementioned drawbacks to be overcome, and to this end, it is based upon the use of a digital micro-processor, which allows all adjustment procedures during manufacture to be eliminated, and for any kind of timing characteristic curve to be obtained.

The new delayed action protection device depending on an adjusted magnitude, as may be seen from Figure 1, is comprised of:

- A transformer (1) for adapting the current in the line it is proposed to protect, where said transformer is fitted with a number of taps to allow the transformation ratio to be adapted.

- A resistance (2), wherein a voltage proportional thereto appears whenever a current that is proportional to the primary current circulates in it. This voltage is filtered by the band pass filter (3) which rejects the peaks and troughs.
- An analogue-to-digital converter (4), which turns the above signal into a digital reading for subsequent processing. Such signal conversion may either be accomplished by the use of an analogue-to-digital converter, such as that illustrated in Figure 1, or by the use of an analogue-to-digital converter (not illustrated) which is goverened by the processor. The processor compares the signal it receives against the preset values. Such preset values are predetermined in a digital form, either by means of codified digital switches provided for the purpose, or by means of instructions transmitted in digital form from outside.

From now onwards, the processor is in possession of sufficient data to enable it to take decisions to trip and to calculate the times suitable for each situation.

There are two different modes of operation envisaged:

In the first mode of operation, the tripping delay times (ta) (See Figure 2) are obtained by direct calculation on the basis of the equations which define different kinds of curve. Hence, on the assumption that an extremely inverse curve as defined in B.S. 142 has been chosen in the protection, the equation defining the delay is:

$$ta = \frac{K}{i^2 - 1},$$

where $i = \frac{I}{I_n}$; that is to say, the ratio between the real I value which flows through the current transformer (1) primary, and the nominal $I_n$ value as rated or preset in the protection by the selector (6); and where K is a constant comprising another of the preset values. Three time curves are shown in Figure 2, and these correspond to three values of K = K1, K2 and K3 respectively.

In a first step, the micro-processor $\mu P$ calculates the value of i by means of the real current and the nominal value. On the other hand, and as has already been mentioned, constant K is a preset value incorporated into the protection, and which defines the particular timing characteristic for K = K1; K= K2; K= K3, etc., from among the family of curves.

Thereupon, by applying these two values K and i to the B.S. equation, the micro-processor calculates the tripping delay time. (ta).

Bearing in mind that the real current value (I) during the disturbance will not necessarily be constant, but will rather develop with respect to the time, the tripping delay time will need to be recalculated. Moreover, as the purpose here is to rival a Ferrari disc system which integrates values with the course of time, the same needs to be done in this case; that is to say, when a new value of ta is calculated, it must be influenced by the "history" in the disturbance from the time it appeared, or, in other words, the protection must be such as to take account of the time elapsed up to the moment when the real current value (I) alters.

This correction is made in the following manner: at the instant when the first disturbance appears, the value of ta1 is calculated, and the time begins to be measured; while in following time intervals, the measurement goes on being analysed, and if there is any variation in such measurement, then the new time is calculated as follows:

$$ta2\ (\text{remainder}) = \left(1 - \frac{T1}{ta1}\right).\ ta2,$$

where:

- ta2 (remainder) denotes the time that must elapse before tripping with the new i2 ratio takes place, and in which time, account is taken of the disturbance development "history";

- T1 is the time elapsed with i1 up until when the second current (and hence the i2 ratio) appears;

- ta1 denotes the trip delay time which would have existed in case 1, that is to say, the tripping delay time as calculated on the basis of i1;

- ta2 is the trip delay time which would have existed in case 2, that is to say, had i2 been present from the very moment the disturbance appeared.

In this manner, the real operating time is an integral function of the disturbance development, in the same way as happens with the Ferrari type electro-mechanical relay. Once the last ta2 (remainder) updated time has elapsed, the µP gives the order for the output relay (106) to close.

In the second mode of operation, the trip delay time is calculated with tables instead of being determined by direct calculation.

To this end, a pre-adjusted timer which increments at fixed intervals of time, is placed in the Central Processing Unit, and tripping of the protection takes place when the timer value is equal to or exceeds a prescribed preset value. This value is obtained by means of a previous study of the curve to be obtained, of the admissible ta errors, and of the available calculating speed.

The required integration, together with the obtainment of the tripping delay times, are achieved by varying the timer increment magnitudes in proportion to the ratio i between the real current and the nominal current values.

For example:

- Let the timer prescribed value be 5,000;
- Let the timer interval incrementing time be 5 m.secs.;
- Let 1 sec. be the tripping delay time for twice the nominal current. This means that when such overloading is maintained constant throughout the disturbance, the timer increment value is $\Delta c = 5000x \frac{0.005}{1} = 25$;
- Let 0.5 seconds be the tripping delay time for four times the nominal current. In this case (assuming that this overload remains constant throughout the whole disturbance) the timer increment value is $\Delta c = 5000x\frac{0.005}{0.5} = 50$.

The protection equipment gauges the current, and finds a value twice as large as the nominal current, and using this value, it refers to the increment table where it finds a Δc value equal to 25, this value being added to the timer every 5 m.secs., and in the event of there being no alteration to the adjusted magnitude i, the timer will reach its prescribed value of 5000 after 200 intervals have elapsed, whereupon the elapsed time will be 1 second Once the prescribed value is reached, the μP gives the order for the output relay (106) to close.

Let it now be assumed that the disturbance develops fourfold during the time counting period. The new measurement will then obtain an increment value of Δc equals 50, this being the new increment to be added in the timer; this moreover having integrated that time during which the disturbance remained at twice the nominal current value, and henceforth the timer will add a series which is double to what it was in the preceding case, since the trip delay time is now half what it was before.

It is to be noted that if at any time during the process, the real current (I) drops below In, the timer returns to zero immediately.

This system rivals the electro-mechanical disc type relay insofar as time integration is concerned, because the value reached by the timer whilst the disturbance has a value of i = 2 is analogous to the motion undergone by the induction disc throughout that time; and, when the disturbance increases, and with it the timer Δc increment, the integration process is similar to the disc speed increase.

The timing characteristic curve thus obtained is a jagged approximation to the desired curve; but nonetheless, by choosing the timer prescribed value, the time interval for timer increment, and the average current value, all in a suitable manner, it becomes possible to obtain an average whose errors are very much smaller than those normally obtained in the standards by which these curves are defined.

It is to be noted that the timer characteristic curves may be any curve, and amongst these are the ones obtained on the basis of the time curves specified under B.S. 142; but here a fixed, additional and optional time is added to the said curve delay times, this not being dependent upon the parameter being gauged (which in the case here, is the current). Said fixed, additional and optional time comprises one of the prescribed values in a reference magnitude to be determined by (7).

Up to now an explanation has been given as to the behaviour of the protection, by way of a description of its components and its operation when it performs the function of an inverted time overload relay, but its functions do not end here, but instead the same components as above, and simultaneously therewith, may optionally embody an instantaneous trip feature, operating as from a given value of i, where this value is considered as the prescribed value, and must be defined when said feature is used. In this case, the protection will behave like an instantaneous overload protection relay. The prescribed value of i is set upon the desired instantaneous trip value selector (8), and in this case, the microprocessor gives an output signal which closes the instantaneous trip relay (108) when the prescribed value set on the selector (8) is exceeded.

The protection device may also simultaneously adopt other functions too, as for example perform a constant watch whereby the processor ensures that the magnitude to be measured (adjusted magnitude) develops in the proper direction; or, for example, to ensure that the present current (I) descends below In before the end of a predetermined period of time as preset on the desired watch time value selector (9). In the event where, upon expiry of such watch time, the adjusted magnitude has failed to develop in the proper direction, the protection will cause the second order alarm output relay (109) contacts to trip. In this way, a watch is kept, for example, to ensure that after the protection has ordered the circuit to trip, and where such condition was caused by a fault in the operation of a switch, then such tripping will not take place; whereupon and by virtue of this new function, once it is checked that no tripping has taken place within the time as preset on selector (9), the switch operating failure is detected and thereupon the alarm is given by means of its output relay (109), this being a second order alarm, because it denotes that a disturbance has taken place, that the protection device ordered action to be taken, but that no such action was taken.

Moreover, the protection device constructed in accordance with this invention may embody further watch functions, and in this regard there is the one whereby the processor watches the development of the disturbance, and if same disappears, then the processor allows a period of time to elapse (as pre-established on the desired reset time value selector), at the expiry of which, the adjustment component (110), comprising an output relay, closes its contacts and re-establishes the service, in such a manner that there is the possibility of an automatic service resetting feature which operates when the disturbance causing it to trip at the end of a certain length of time, has disappeared.

Moreover, the invention being dealt with here may also ensure that if, before a further period of time has elapsed (as preset on the desired locking time value selector (11), and which may here be termed "the locking time", the disturbance was to reappear, then the service restoring function, as referred to in the preceding paragraph, would become locked, and thus prevent operation of the reset output relay (110). In this way, the risk of "hunting" is avoided, that is to say, when the service restoring function has operated, there is a reappearance of the disturbance and as a result tripping recurs, whereupon the service restoring service operates again, and so on, wherewith the main switch goes on opening and closing continually due to the real cause of the disturbance not having been eliminated. With this function as described, the invention would act as a protection against successive recurrences of the disturbance.

Each one of the aforementioned functions, (with the exception of the desired additional constant time value selector (7), caters for memorizing and signalling of its operation by means of light emitting diodes (LED), which will remain lit until such operation is erased from their memory, which may either be accomplished locally (by means of a press button), or by means of outside signals.

Hence, signal (206) shows tripping at the value prescribed on the desired nominal current value selector (6).

Signal (208) shows tripping at the value prescribed on the desired instantaneous trip value selector (8).

Signal (209) shows tripping at the value prescribed on the desired watch time value selector (9).

Signal (211) shows tripping at the value prescribed on the desired locking time value selector (11).

From all the foregoing, it may be seen how, in accordance with the invention being dealt with here, it is envisaged that in a single protection device, and in a combined manner, it is possible to perform simultaneously the functions of an inverted time overload relay, an instantaneous overload relay, a switch operation failure detector, or second order alarm, and a service restoring relay, with protection against multiple recurrence of the disturbance.

The new electrical protection device covered by this invention may obviously be used too for the purpose of performing solely one of the functions described above, by means simply of suppressing the others.

CLAIMS:

1. A delayed action electrical protection device, characterised in that it includes an analogue-to-digital converter adapted to convert an input magnitude into a digital signal which is applied to a micro-processor in which is stored information defining relationships between time delay and magnitude of departure of the digital signal from a set value, said micro-processor being adapted to provide an output tripping signal after a time delay determined by said stored information if said digital signal departs from said set value.

2. A protection device as claimed in Claim 1, characterised in that the information stored in said micro-processor defines a plurality of characteristic curves, relating time delay to the ratio of said digital signal and said set value.

3. A protection device as claimed in Claim 1, characterised in that the information stored in said micro-processor is in the form of tables relating time delays to ratios of said digital signal and said set value.

4. A device as claimed in any of the preceding Claims, characterised in that the set value is fed into the micro-processor by means of a plurality of digital switches.

5. A protection device as claimed in any of Claims 1 to 3, characterised in that the set value is fed into the micro-processor by means of a remote control or transmission system.

6. A protection device as claimed in any of the preceding Claims, characterised in that the time delay is inversely proportional to the input magnitude.

7. A protection device as claimed in Claim 6, characterised in that the input magnitude is the value of an electric current, in that the micro-processor provides a digital form of the present current value together with the result of a calculation based on an inverted delay time curve using a preset constant, and in that the output signal is applied to inverted time overload protection relay.

8. A protection device as claimed in Claim 7, characterised in that a fixed, additional and optional time, which is not dependent on the magnitude being measured, is added to the delay time as obtained from the timing curves, and in that such fixed, additional and optional time comprises one of a plurality of prescribed values to be set in by an appropriate selector.

9. A protection device as claimed in any of the preceding Claims, characterised in that means are provided for entering an instantaneous tripping value into the micro-processor and in that said output tripping signal is produced immediately when the digital signal corresponds to an input magnitude which exceeds said instantaneous tripping value.

10. A protection device as claimed in Claim 9, characterised in that the input magnitude is an electric current, and in that, when the ratio between the present current and a nominal current exceeds a preset value, the device operates as an instantaneous overload relay.

11. A protection device as claimed in any of the preceding Claims, characterised in that after the micro-processor has provided the output tripping signal, it will watch that the input magnitude develops in the right direction before the expiry of a pre-established time, which is preset as a prescribed value, and after the end of which, the micro-processor orders an output relay to close if no such development has taken place in the right direction.

12. A protection device as claimed in Claim 11, characterised in that the input magnitude is an electric current, and in that the device behaves like a switch tripping failure detector or second order alarm.

13. A protection device as claimed in any of the preceding Claims, characterised in that after the micro-processor has provided the output tripping signal, it watches the development of the disturbance in the input magnitude, and once said disturbance has disappeared, allows a predetermined time as set as the preset value on a selector to elapse, whereupon it orders an output relay to close, thus allowing the service to be restored, and where, should the disturbance arise again in the micro-processor before a new predetermined watching time set as the preset value on another selector has elapsed, then, in addition to ordering the trip, it would order the service restoring relay to become locked, so that in this way the device behaves like a service restoring relay with protection against multiple recurrences.

14. A protection device as claimed in any of the preceding Claims, characterised in that light emitting diodes are employed to signal the performance of the device, such diodes remaining alight from the time the tripping signal is produced until they are extinguished by means of a local push button, or by remote control.

15. A protection device as claimed in any of the preceding Claims, characterised in that it performs the functions of an inverted time overload relay, an instantaneous overload relay, a switch-operating failure detector, or second order alarm, and a service restoring relay, with protection against multiple recurrences.

16. A protection device as claimed in Claim 1, characterised in that said micro-processor calculates the delay time as the ratio of a preset constant to a function of the input magnitude minus 1.

17. A protection device as claimed in Claim 16, characterised in that said function is the square of the ratio of the input magnitude to the set value.

18. A delayed action electrical protection device, characterised in that it comprises an analogue-to-digital converter adapted to measure a signal denoting the adjusted magnitude to be watched, and of turning it into digital information for subsequent processing, and a micro-processor for processing the information which is digitally in accordance with timing characteristic curves that relate the tripping delay time to said adjusted magnitude, and for performing the digital comparison between the prescribed values and the values of the signals as received from the converter, and ordering tripping if there is found to have been a disturbance in the adjusted magnitude, provided that the delay time, that corresponds to the size of the disturbance, has elapsed.

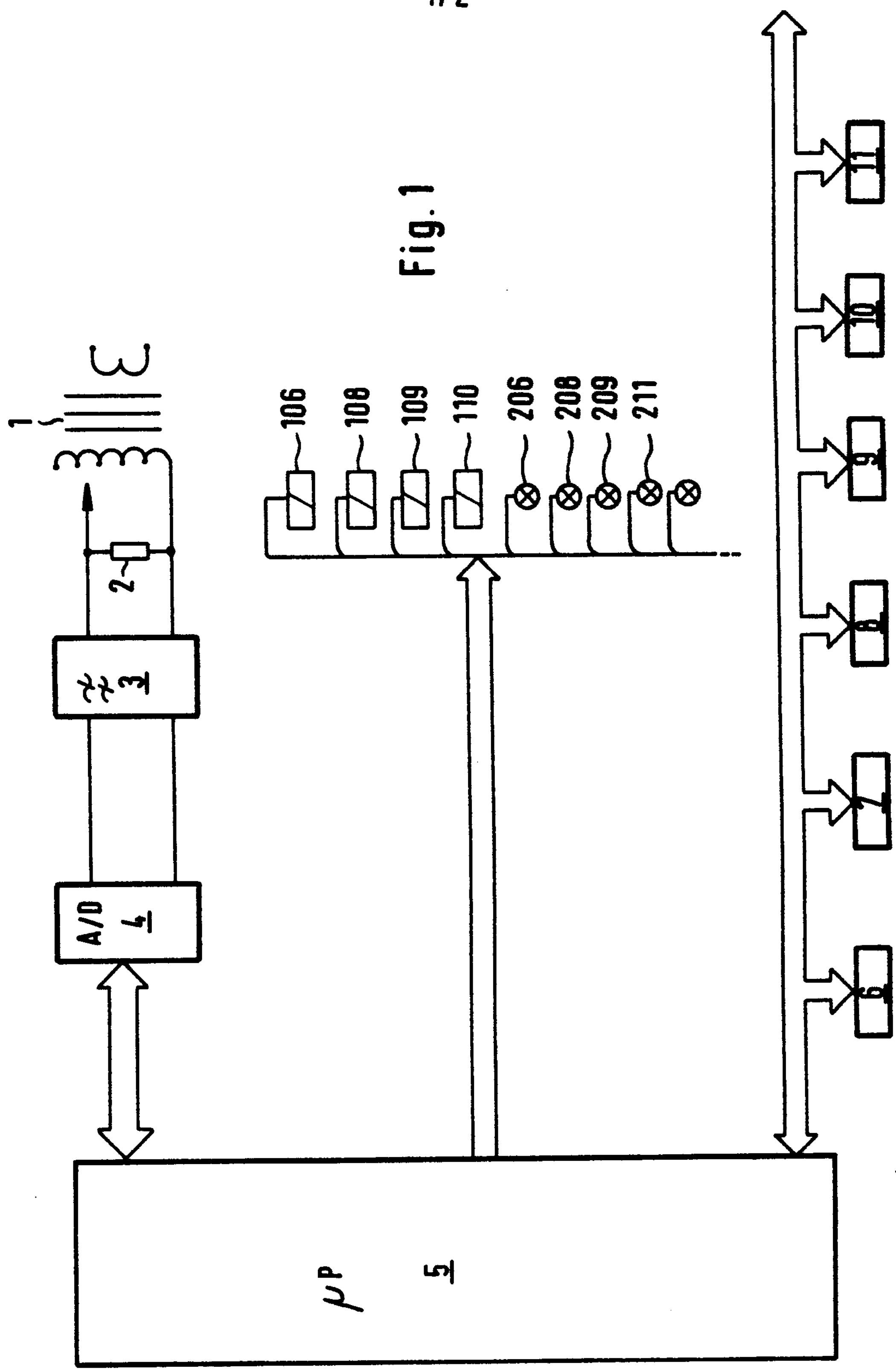
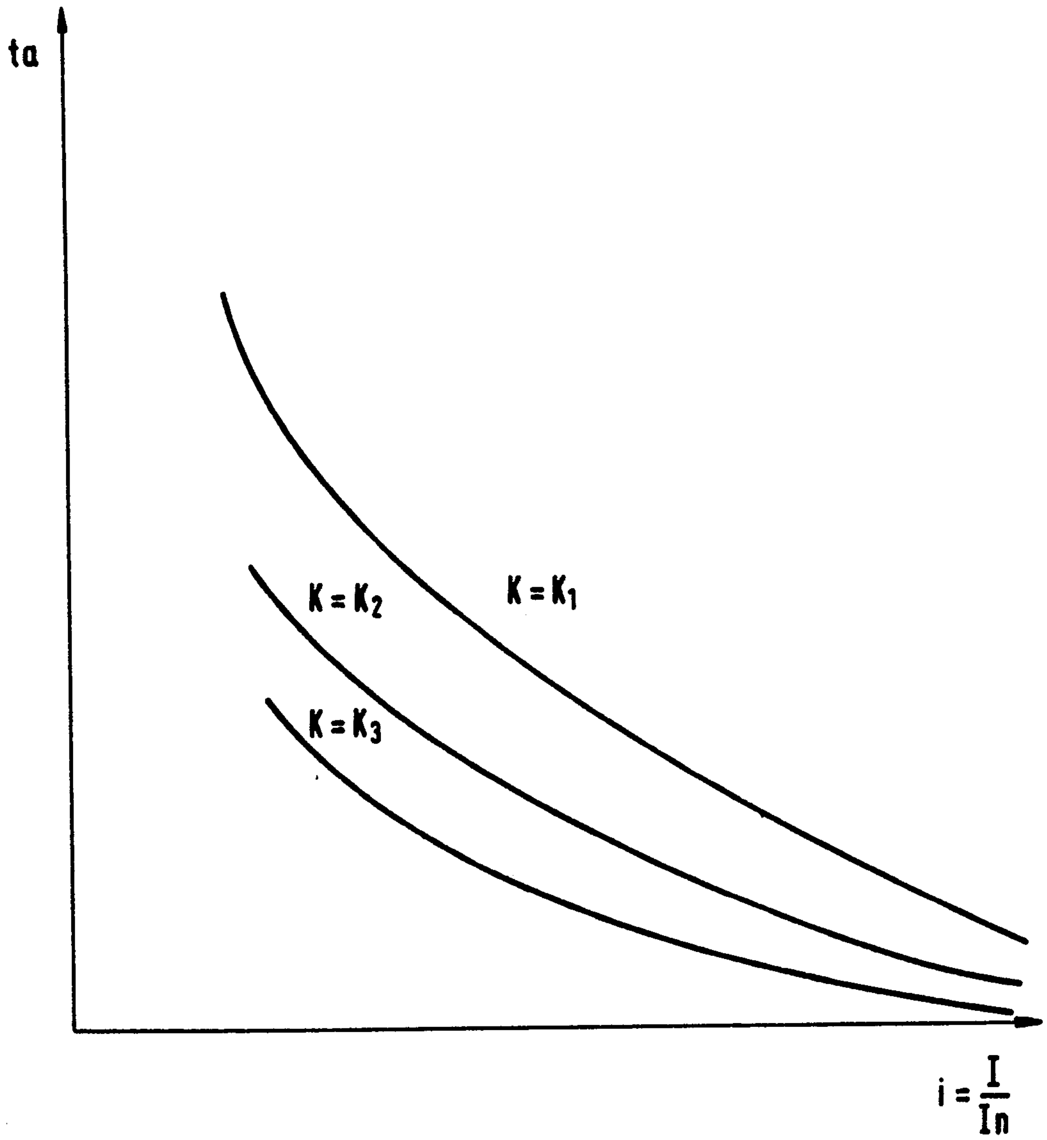



Fig. 1

Fig. 2



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**EUROPEAN SEARCH REPORT**

Application number
EP 79 30 0571

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim |
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**CLASSIFICATION OF THE APPLICATION (Int. Cl.²)**

H 02 H 3/08
H 01 H 71/44
H 02 H 3/06

**TECHNICAL FIELDS SEARCHED (Int.Cl.²)**

H 02 H 3/08
5/04
G 06 F 15/56

**CATEGORY OF CITED DOCUMENTS**

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 16-07-1979 | SIMON |

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# EUROPEAN SEARCH REPORT

Application number
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| DOCUMENTS CONSIDERED TO BE RELEVANT | | | CLASSIFICATION OF THE APPLICATION (Int. Cl.³) |
|---|---|---|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | |
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